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# Two Dimensional Beam Smoothing for Direct Drive Inertial Confinement Fusion using Spectral Dispersion

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**Abstract:** Numerical simulations of the smoothing of speckled intensity using frequency modulation and grating dispersion in two dimensions are presented. The variation of the orthogonal modulation frequencies dramatically affects the dynamic smoothing and spatial structure of the intensity.

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Inertial confinement fusion (ICF) utilizing direct laser drive is thought to require a high degree of driver intensity uniformity. A number of approaches have been suggested to achieve the desired level of 1% RMS intensity variance.[1-5] The use of random phase plates (RPP)[2] in conjunction with angular dispersion of frequency modulated (FM) light (termed smoothing by spectral dispersion-SSD)[4] holds much promise for ICF using mega-Joule class glass lasers. This method has been analyzed and measured for dispersion in one dimension.[4,5] However, smoothing by 1D SSD is insufficient to reach the smoothing levels required for direct drive ICF, and it is necessary to disperse the driver beam in both orthogonal dimensions (2D SSD). This can be accomplished by sequentially applying FM, dispersion by a grating, applying FM at a second frequency, and orthogonal dispersion by a second grating.[6] After transmission through a RPP a temporally varying speckle pattern is produced at the focal plane. In one perspective the speckle pattern moves over many decorrelation lengths, and the integrated intensity variance is thereby reduced according to $\sigma = n^{-1/2}$ , where $n$ is the number of independent decorrelated speckle patterns.

In the case of 2D SSD one must use two modulators with incommensurate frequencies, otherwise, the two dimensionality of the SSD is not fully exploited. To see this effect, the interplay of the modulation frequencies in 2D SSD is calculated in the case where one frequency is 10 Ghz, and the second is 3.6, 5, 7.5, and 10 Ghz. The modulation depths at each frequency are set such that the bandwidth generated by each modulator is 500 Ghz (e.g., on the third harmonic light). The dispersion is adjusted in each dimension to shift adjacent FM sidebands by one speckle decorrelation length. Figure 1 shows the time variation of the effective number of decorrelated speckle patterns, $n = 1/\sigma^2$. In the case of ideal smoothing, one expects $1/\sigma^2 = t\Delta\nu$, where $\Delta\nu$ is the bandwidth. The observed oscillatory behavior is a result of periodic cycling of speckle patterns (owing to the relationship between the two modulation frequencies), which has the effect (after normalization) of increasing the variance, and thus decreasing the effective number of decorrelated patterns. By correct choice of the incommensurate second frequency (e.g. 3.6 Ghz), this repetition effect can be minimized and the full bandwidth is utilized to reach the asymptotic smoothing level (roughly set by the product of the number of sidebands from each modulator).

It is also of interest to examine the spatial structure of the smoothed intensity pattern produced by 2D SSD. An example is shown in Fig. 2. This calculation assumes 10 and 0.9 Ghz as the modulation frequencies, and the dispersion is set to shift each FM sideband by 1.25 decorrelation lengths. Just as 1D stripes are apparent in 1D SSD, a 2D periodic structure is clearly observed in this case. The nature of this structure is strongly dependent on the modulation frequencies and angular dispersion chosen. The appropriate choice of these parameters is investigated, by which

it is possible to manipulate the nature of the smoothed speckle pattern, and thereby optimize the interaction with the ICF target.

## References


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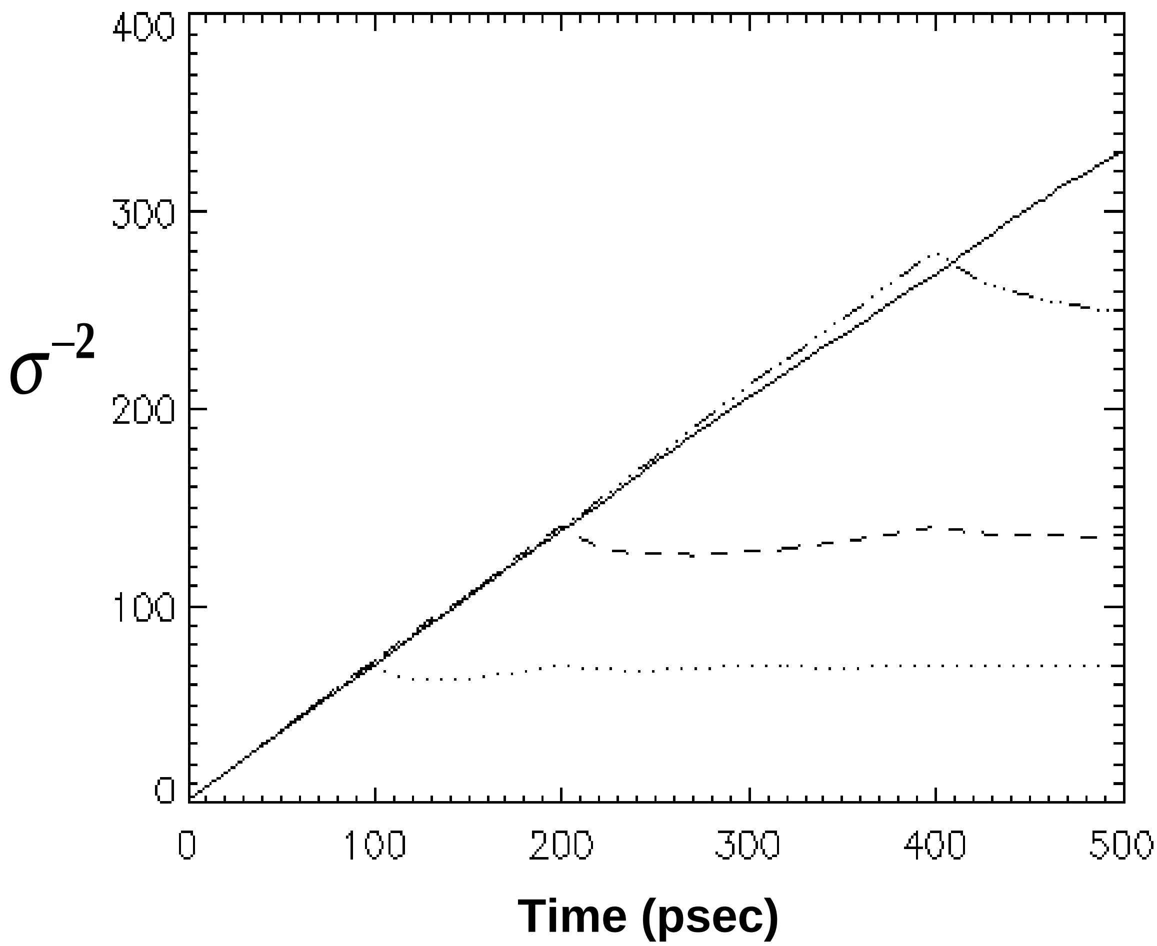
## Figure Captions

Figure 1: Variation of the effective number of decorrelated speckle patterns $(\mathbf{1}/\sigma^{\mathbf{2}})$ with time for 2D SSD. One modulation frequency is 10 Ghz, and the other is 10 (dots), 5 (dash), 7.5 (dot-dash), and 3.6 Ghz (solid).

Figure 2: Smoothed intensity pattern generated by 2D SSD with modulation frequencies of 10 and 0.9 Ghz. The horizontal width corresponds to a divergence 22 times the decorrelation of a speckle pattern ( $\lambda$/D , where D is the (square) input aperture width).

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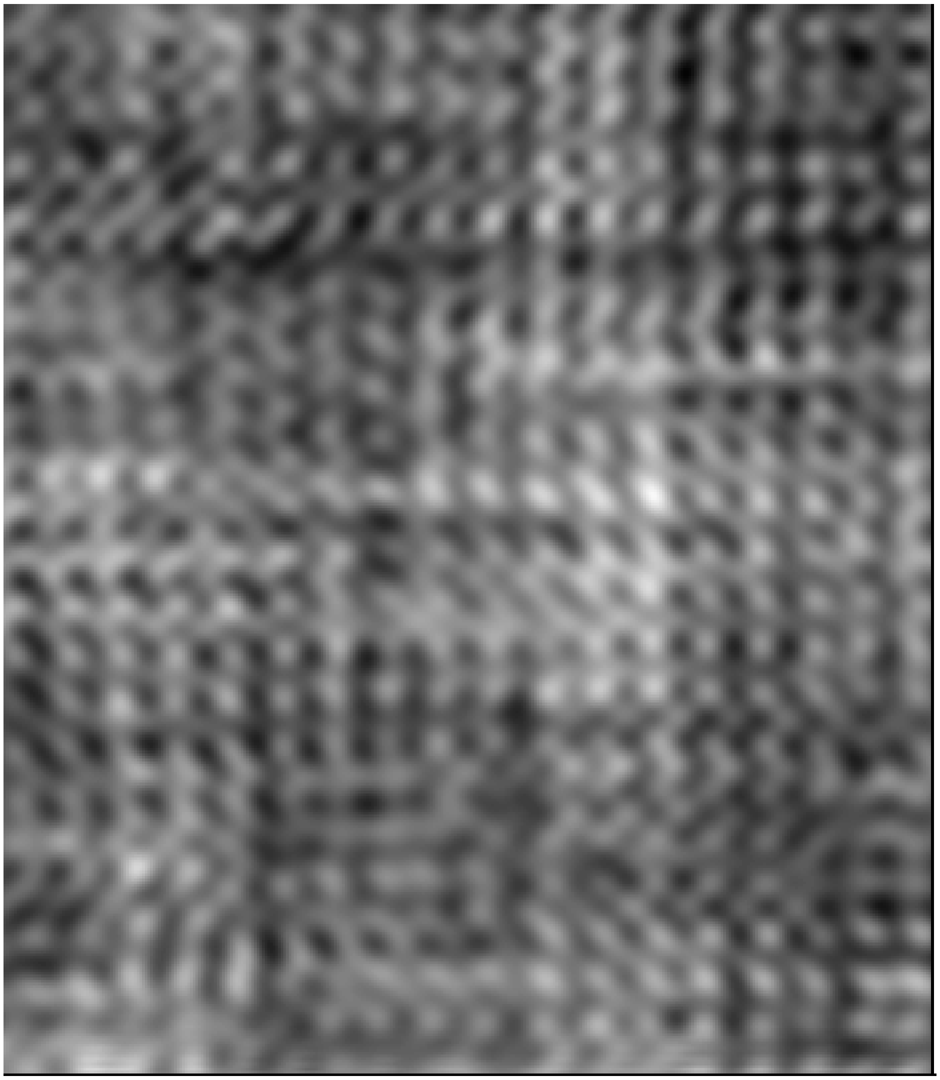

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